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1. Your reference

2. Patent application number
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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*
JOHN PHILIP ROGER HAMMERBECK
RAWLINGS HOUSE
2a MILNER STREET
LONDON SW3 2PU

~~05903871002~~
Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention
RATIO CHANGING METHOD AND APPARATUS

5. Name of your agent *(if you have one)*
KILBURN & STROPE

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

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Description	10
Claim(s)	3
Abstract	
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11. I/We request the grant of a patent on the basis of this application.

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Ratio Changing Method and Apparatus

Reduction of rotational frequency and, less commonly, generation or increase of rotational frequency are often required when linking a motor to a load. It is also useful to produce a variable output from a variable input. The present invention proposes to change rotational frequency and provide a continuously variable drive by a new variation on the oscillating hypocycloidal principle.

Background

The hypocycloidal principle involves making a gear wheel "walk" round the inner circumference of a ring gear, or vice-versa, thus imparting a rotation to the other member that is counter to the direction of oscillation. Commercially available groups of reducers use a similar principle. The most common is the harmonic wave drive which uses a flexible geared spline which is pressed by an inner wave generator at opposite points against an outer fixed gear ring, thereby transferring rotation to the flexspine at high reduction ratios. The output rotates contrary to the input, which is advantageous because it reduces the reaction force required to be supplied by the mount. However, this type of reducer is expensive, the flexspine is subject to fatigue failure and it cannot be made continuously variable. The layout is that an inner dual pressure wave input forces a flexible end of a cup shaped transfer ring against a fixed outer ring. Output is taken from the rigid bottom of the cup and is in a contra direction to the input.

It is also known to use a non flexible hypocycloidal principle whereby the input is divided between two or more eccentric cams rotating within a ring having

internal gears and causing it to wobble round an inner gear and so impart rotation to it. This design has low torsional wind up, but is complex and sliding of the eccentric cams make it inefficient. The layout is that multiple eccentrics rotate in holes in a ring with internal gears causing the ring to oscillate round an inner output gear, producing rotation contra to input direction.

A further type of hypocycloidal drive sometimes called a quadrant drive uses a cam on the input to cause a gear to wobble and roll round within a ring gear from which output is taken. The layout comprises an eccentric central input which rotates within a central gear wheel causing it to oscillate against the geared inner side of a fixed ring gear. The reaction produces a contra rotation in the oscillating gear. A further eccentric stage cancels the oscillation to produce simple rotation.

A further group is the cyclo drive. This design is inherently expensive because of the large numbers of components and roller bearings. It employs an eccentric inner input to oscillate a central disc, which is restrained by outer rollers. The output means has roller pins, which extend into holes in the oscillating disc. Output is contra to input. This is essentially the same layout as the quadrant drive except that the eccentric output is cancelled by the roller pins on the output, rather than by a separate stage.

Description

The present invention proposes to employ hypocycloidal means as shown in principle in fig 1 by oscillating a intermediate transfer ring (1) by means of a rotating pressure input embodied in a freely rotating wheel (2), that is co-axial with an inner output (3). The transfer ring is compliantly tethered by suitable

means to prevent it rotating. Increased leverage makes the force applied rise steeply when the pressure (2) rotates and tries to force the contact point (5) with the intermediate ring (1) off a notional line (6) connecting the contact point and centres of the output wheel and the transfer ring. Output direction is contra to input. The rotating pressure may be on the outside of the transfer ring, pressing the transfer ring directly against the inner output wheel, or may act on the inside of the transfer ring, pressing outwards and forcing the opposite side of the transfer ring against the inner output wheel. Also the rotating pressure may consist of two or more pressure points on either side of the contact point between transfer ring and inner output wheel. Transfer of torque between the transfer ring and the output wheel may be by usual friction means or by positive means such as teeth or roller teeth.

This layout is less expensive than previous hypocycloid layouts and can be employed in both friction and positive embodiments. It can be used in both fixed ratio and continuously variable embodiments.

The present invention is capable of being finely balanced because the input and the transfer ring move as one mass with unchanging weight distribution.

Optional disconnection of output from input can be effected by moving the rotating pressure wheel or wheels away from the transfer ring, allowing the transfer ring to disengage from the output wheel. This is suitable for friction versions because of the ease of re-engagement between smooth surfaces. A method suited to both friction and geared output, is to release the tether on the transfer ring. In this method the transfer ring is attached by compliant means to a base that is selectively free to rotate. When the base is allowed to rotate, the transfer ring rotates with the output and no torque is passed to the

output. A brake applied to the rotating base stops the base rotating and torque is transferred to the output. The level of friction applied by the brake after lockup can be selected to give torque limiting overload protection. This clutching method is more difficult to implement with continuously variable versions because the actuation for changing the transfer ring becomes more complex.

Input to the transfer ring can be to the outer circumference of the transfer ring or to an inner circumference of a transfer ring. The tether can be a compliant ring, tube, membrane. spring, bellows or other suitable compliant tether to prevent the transfer ring from rotating. The tether may act on the ring from a mount from any suitable direction, but radially outwards or inwards or co-axial with the output are most advantageous. Because the transfer ring can be sealed at the input end when input is to the outer circumference of the ring, or an internal partition can be supplied to divide the output side from the input side when input is to the internal circumference of the ring, the drive can pass rotary power without a rotating seal. Such ability is advantageous in industries processing volatile chemicals or foodstuffs because it prevents the passage of contaminants.

Simple lubrication can be effected by enclosing the transfer ring with a plate on one side and a flexible boot on the side from which output is taken. This boot may form the tether. If the drive is by friction this can seal in a traction fluid. Because the ring wobbles and does not rotate the lubricant or fluid will drip to the bottom of the tether ring, where progressively different portions of the output gear dip into it on each oscillation of the transfer ring. Thus little lubricant is required, reducing losses associated with churning. A magnetic

trap for wear particles may be placed at the base of the oscillating ring. The strength of the tethering forces at varying points around the transfer ring may be adjusted to account for any off balance mass of the lubricant.

In more complex embodiments the transfer ring may be provided with internal channels or surface mounted tubes for the circulation of lubricant or cooling fluid. Lubricant can be pumped efficiently by providing a open tube and one-way valve that is thrust into a lubricant pool under the transfer ring on the downward oscillations of the transfer ring. If cooling fluid is exchanged with an external heat exchanger the oscillation of the transfer ring will cause liquid in channels within or attached to the ring to be thrown in the direction of oscillation. Thus the drive provides its own pumping mechanism.

In a first simple fixed ratio geared embodiment (fig 2), there is provided an input shaft (1) fixedly mounted on which is a leaf spring beam (2). On the other end of the beam is mounted a freely rotating roller (3). On an output shaft (4) co-axial with the input shaft (1) is mounted a gear wheel (5). Between the gear wheel (5) and the roller (3) is sandwiched a substantially circular transfer ring (6) with internal gears. The transfer ring (6) is restrained from rotation by an elastic sheet (7) connected to a rotatable disc mount (8) which can be prevented from rotating by the application of a block brake (9). In operation the input shaft (1) rotates causing the roller (3) on the beam (2) to also rotate around the same axis. This applies a rising compliant pressure to one side of a notional line joining the contact point of the transfer ring and the output gear and their respective centres. This pressure acts on the transfer ring (6) in the manner of a lever against the fulcrum, which in this case is the

contact point berween the transfer ring and the output wheel. The further the pressure moves away from the contact point the greater the leverage. The transfer ring is prevented from rotating by the tethering sheet and cannot rotate, so the pressure forces the inner gear (5) to rotate contra to the direction in which the pressure wheel is rolling. If the rotational force reaction in the transfer ring rises sufficiently to overcome the friction of the brake (9), the rotatable disc mount (8) will slip and rotate, the transfer ring will then rotate rather than wobble and no torque will be transmitted to the output. Slippage can be operator activated to de-clutch the drive, or pre-set as overload protection.

In a second fixed ratio embodiment (fig 3), which operates in the same manner as the first, the tether to restrain the transfer ring from rotating is a number of coil springs (4) which attach the transfer ring to the unit housing. The transfer ring is provided with an internal channel through which cooling fluid is circulated. The cooling fluid is supplied from to and from the reservoir by flexible pipes running through the coil springs and is pumped by oscillation of the ring as described above.

In a third fixed ratio embodiment (fig 4), operating in the same manner as the first, the tether is provided by a bellows (1) connecting the transfer ring to an outer casing (2). A partition (3) is provided in the transfer ring to seal the output (4) from the input side. Thus in operation no matter of any kind can pass from the input side or the output side and rotary power can be passed without the neccessity of a rotating seal. This embodiment is supplied with two input wheels, by way of illustration of the variety of possibilities.

In a fourth fixed ratio embodiment (fig 5.) operating in the same manner as the first an input wheel (1) is provided that rotates within the transfer ring (2) opposite the contact point between transfer ring and inner output wheel (3). The tether is supplied by a rubber ring (4) between the transfer ring and the casing (5). This embodiment is advantageously compact.

The use of pressure waves to drive piezo effect motors is known, but these do not employ a transfer ring to obtain a walking contra rotation effect and rely on direct frictional force to drive the output in the same direction as the pressure wave. In such motors it would be advantageous to use a transfer ring and so increase the torque output through reduction. In a similar manner the present invention may incorporate phased electro-magnetic means to oscillate the transfer ring, which may contain permanent magnets.

The ratio of hypocycloidals is determined by the difference in the length of two interacting surfaces, which roll together. This effect is usually described as arising from the difference in number of teeth rather than difference in length as previous hypocycloidals have all been geared. The surfaces do not have to be endless or fixedly circular. A change in length of either interacting surface changes the ratio. The effect of walking a ring once around an inner wheel in a hypocycloidal manner without slipping is to produce a contra rotatation in the inner ring equal to the difference in the interacting circumferences. From this it will be appreciated that hypocycloids give increasing reduction as the length of their interacting circumferences converge and vice-versa. For example, with a walking ring of inner circumference 65mm and a driven wheel of 54mm the reduction ratio is approximately 5.3:1. However if the driven wheel is expanded to 63.5mm a ratio of approximately 100:1 is obtained. If

the driven wheel is expanded to 64.5mm a reduction ratio of 129:1 results. Thus, by expanding the radius of the output driven wheel by 18% a reduction ratio of approximately 24.3 times the original 5.3:1 ratio is achieved. This is a greater range than any other mechanical continuously variable drive. If a ratio range similar to an auto gearbox is required (5:1) and with overall drivetrain reduction varying between 20:1 and 100:1 a radius change of only 4.15% is required. Either changing the inner circumference of the transfer ring or the circumference of the inner driven wheel, or changing both, changes the ratio. Generally it will be preferred to change ratio by changing the transfer ring, because it wobbles rather than rotates. This enables easy access to the ring for actuation of the change. Locally varying the thickness between inner and outer circumferences of the transfer ring has the effect of a cam within each rotating of the input . This effect can be used to smooth torque and speed fluctuations in the input, such as when the motive power is supplied by an internal combustion engine.

Various methods of changing circumferences can be used, such as mechanical, hydraulic, pneumatic and electric actuators acting on either the transfer ring, the output wheel, or both.

In a preferred embodiment (fig 6.) overlapping ends (1) of an open transfer ring (2) are connected by a variable length screw actuator (3). The transfer ring is sandwiched in pressure contact between an inner output wheel (4) and outer(5) and inner (6) input wheels, mounted on an arm (7) on an input shaft (8) to rotate about the same axis as the inner ouput wheel. In operation the system rotates, oscillate and outputs reduced rotation as described above, but varying the length of the actuator changes the degree of overlap, thus

changing the length of the inner circumference of the transfer ring and thereby changing the ratio. If the ratio is changing while the system is operating, the change should preferably be effected when the overlap is on the opposite side of the transfer ring from the point of contact between the transfer ring and the output wheel. The overlapping ends preferably comprise multiple interlocking fingers (10) which slide together and are sufficiently compliant to allow a smooth passage of the output wheel at all variable lengths. This layout may be frictional or positive. When positive the actuator must move in defined steps to ensure accurate registration of teeth etc. on the two overlapping ends of the transfer ring.

In a second preferred embodiment of a continuously variable version of the invention (fig 7.) operating in the manner described above, the transfer ring comprises an elastic pneumatic tube (1), connected by a flexible tube (2) to a pneumatic controller (3). Rotating pressure is supplied by two wheels (4) connected by a spring (5). The wheels are mounted on arms, which are rotatably mounted on an arm fixed to the input shaft. In operation the input shaft rotates the wheels which are pressed against the transfer ring by the spring forcing them together. The transfer ring oscillates in the above described manner and transfers torque at reduced ratio to the output wheel. Increased reduction is achieved by the controller admitting more air to the transfer ring tube. This expands, and reduces the inner circumference of the tube and so changes the ratio. The effect is reversed by allowing air out of the transfer tube and increasing the ratio. This embodiment would provide a reducer of low mass.

It will be appreciated that there are a large number of different permutations of features described in these preferred embodiments and that different features might be used in particular applications, without departing from the spirit of the invention. It will also be appreciated that the system described can be reversed to provide generation of increased rotary speed.

Fig 1

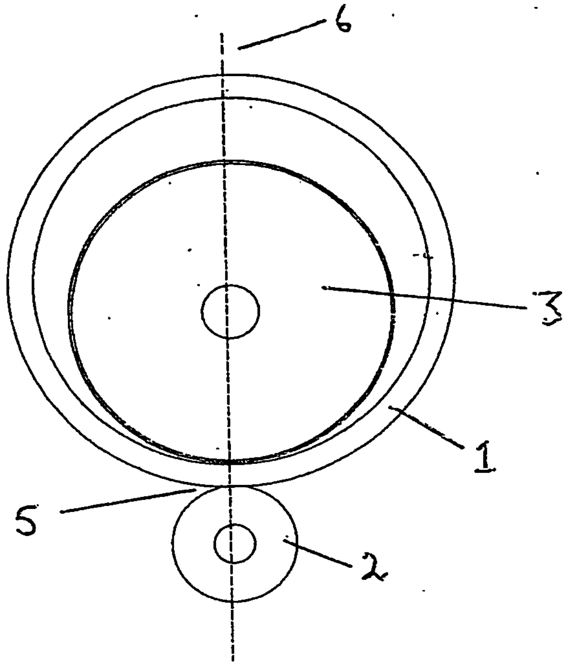

Fig. 2

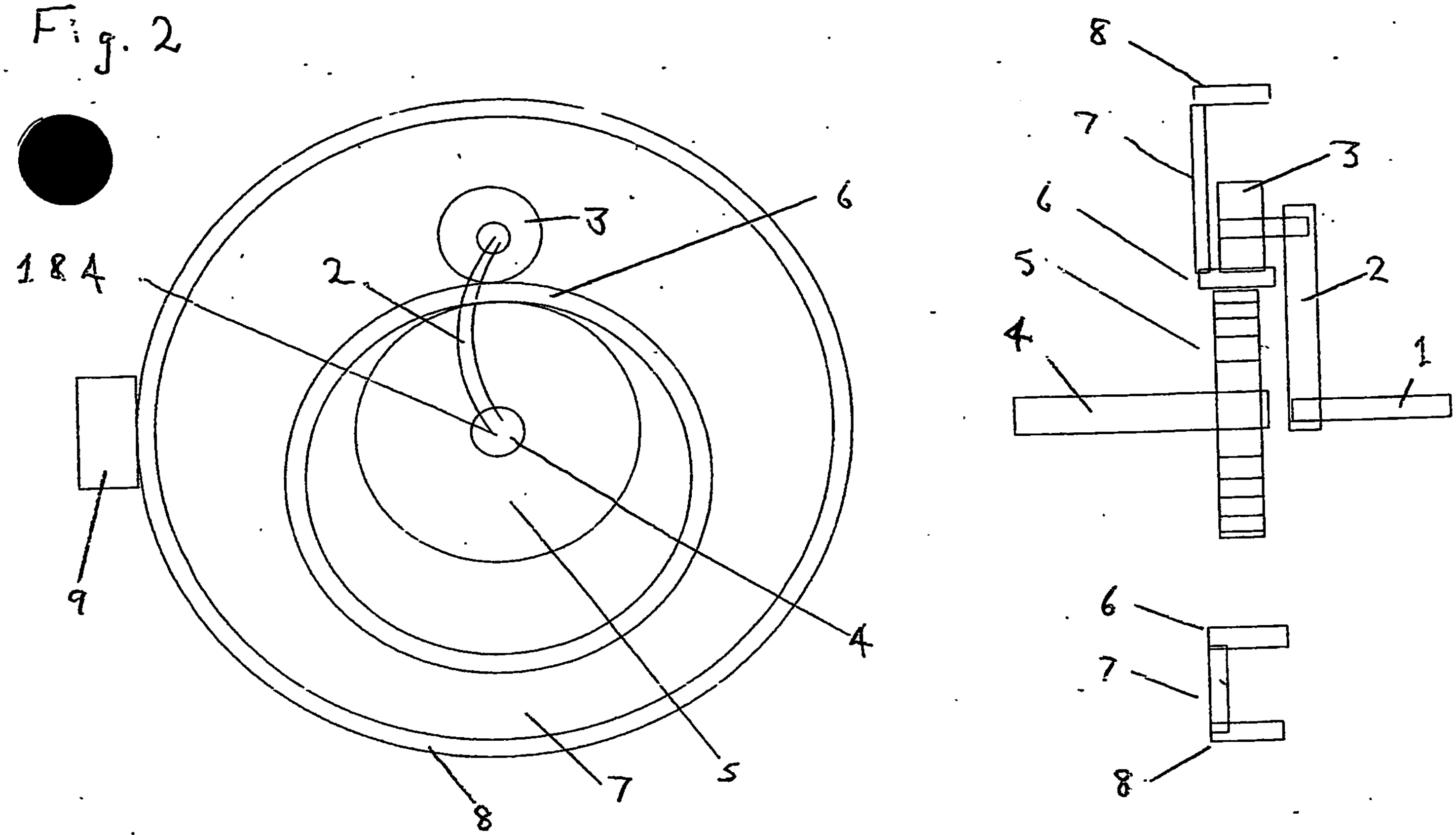

Fig.3

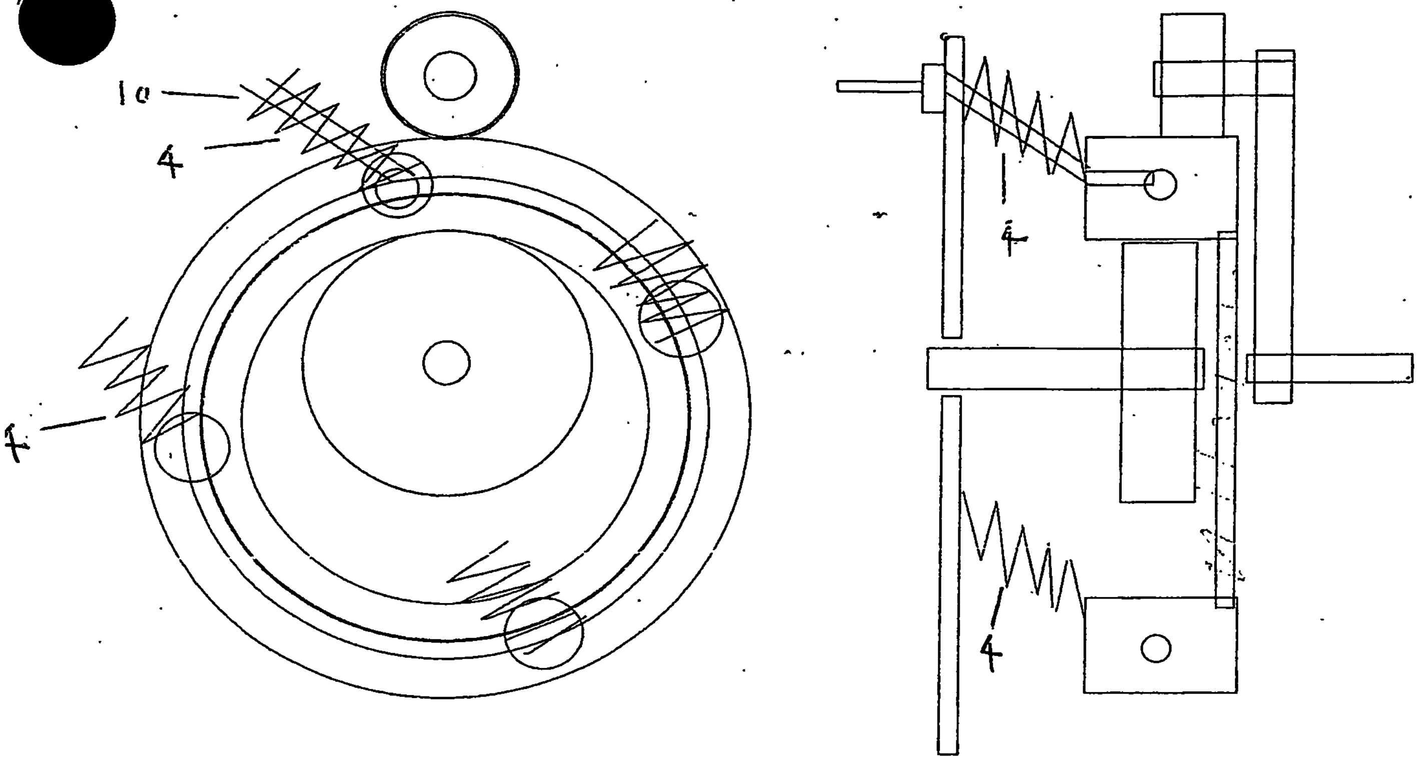

Fig. 4

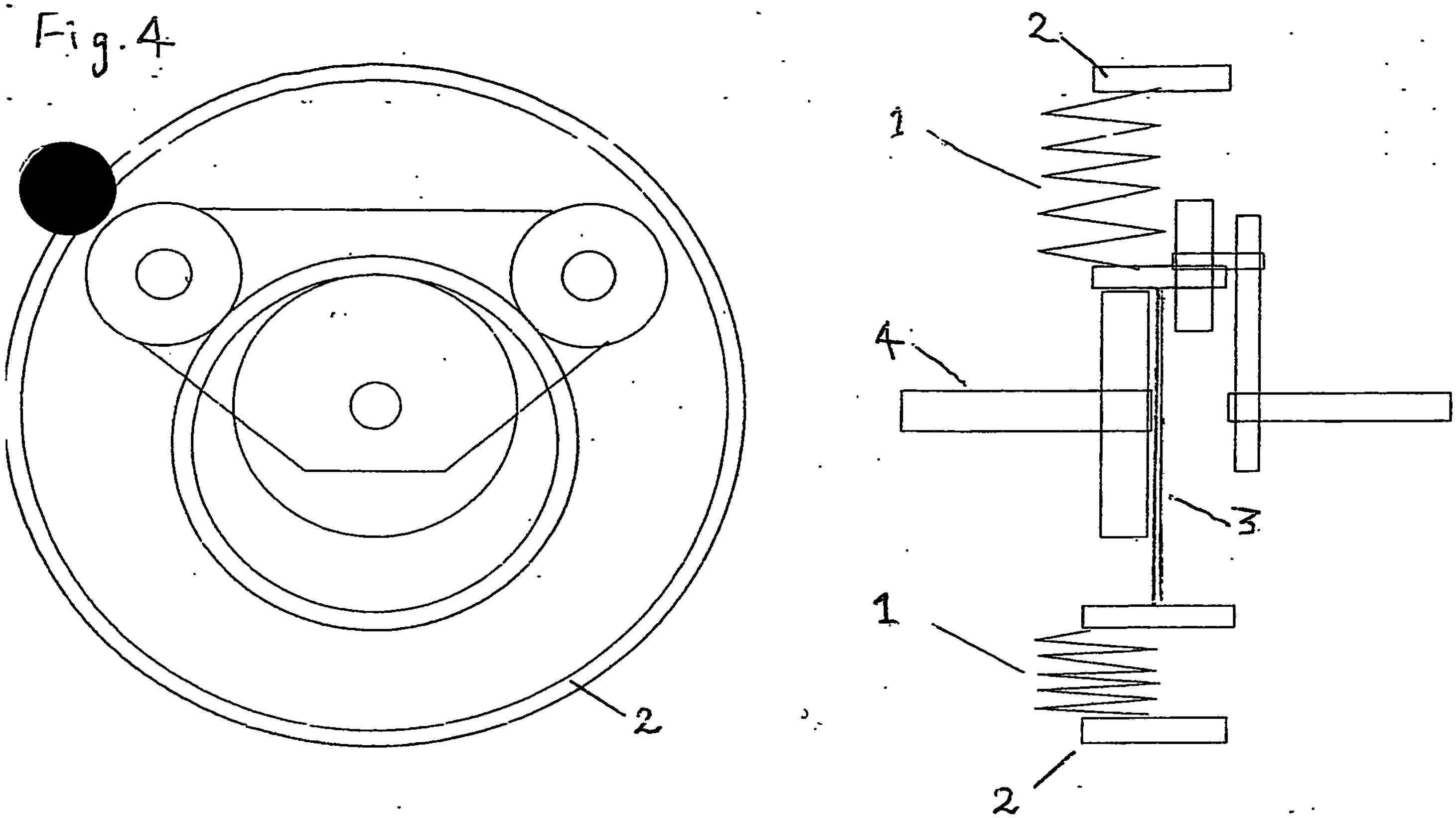

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Fig. 5

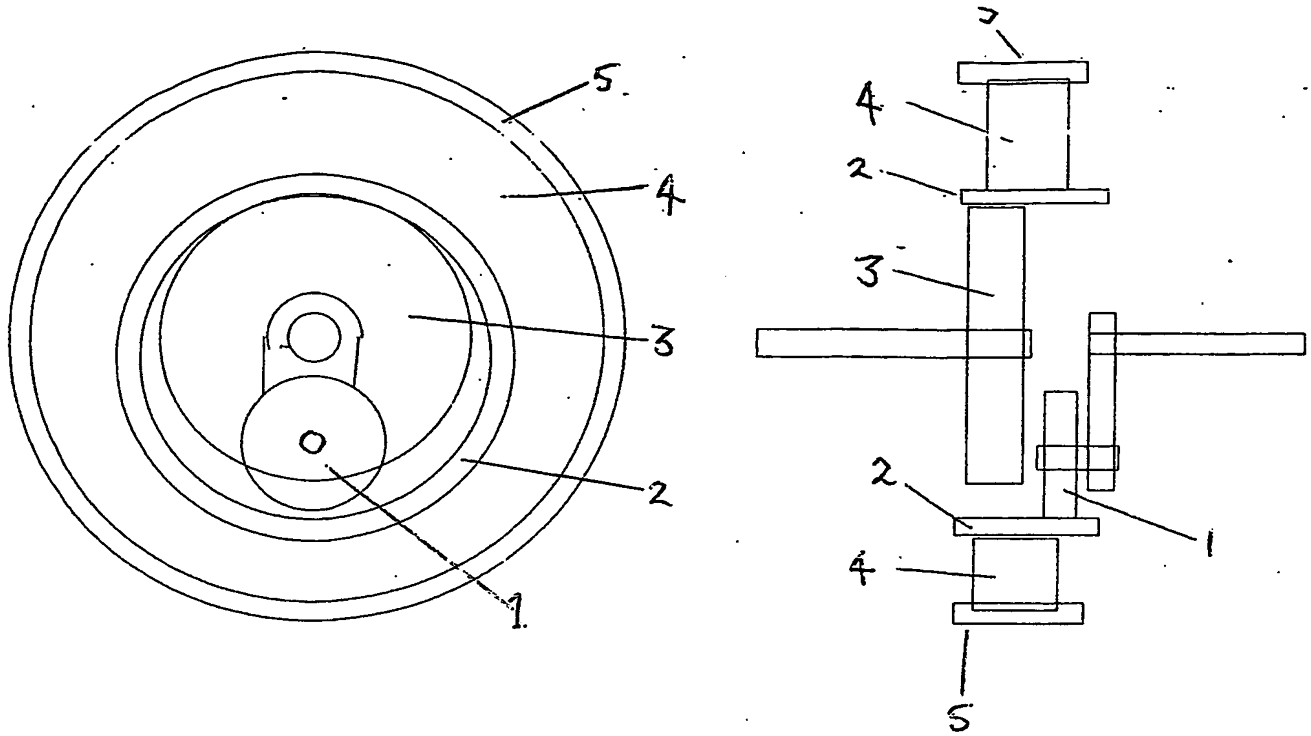

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Fig. 6

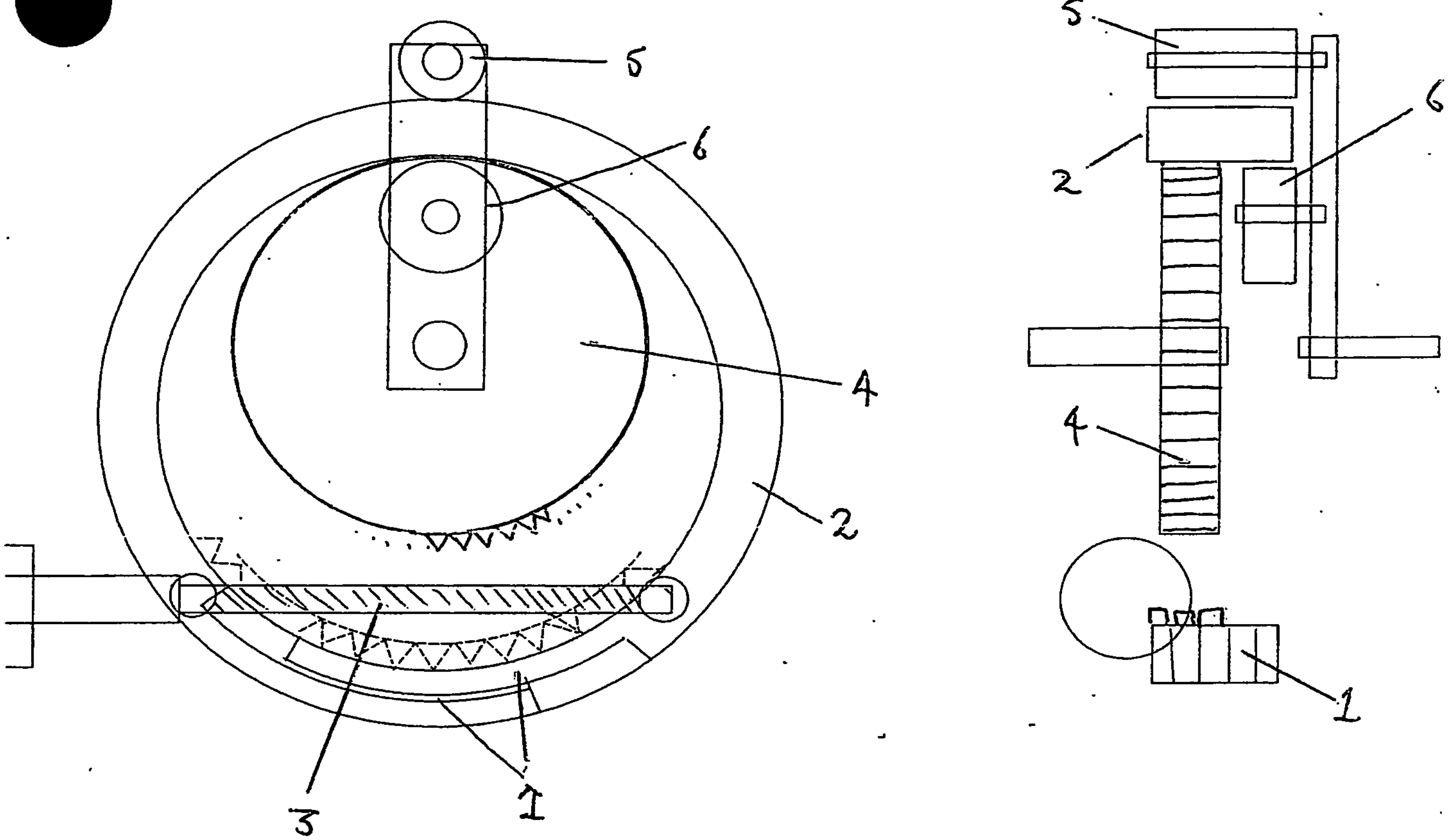
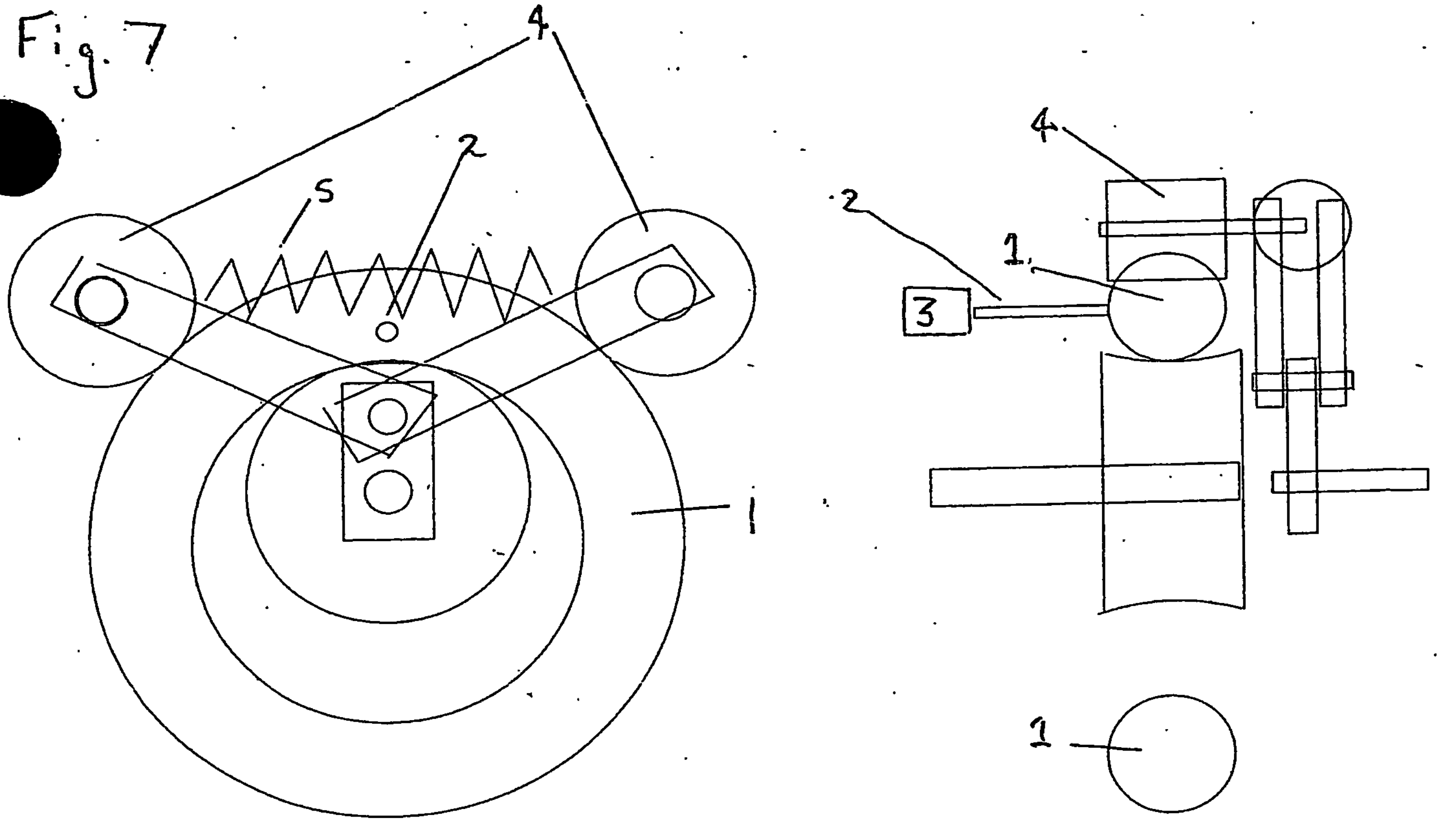


Fig. 7



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